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An Electrostatic Precipitator Backup for Sampling Systems

Southern Research Inst, Birmingham, Ala

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Laboratory
Research Triangle Park NC 27711

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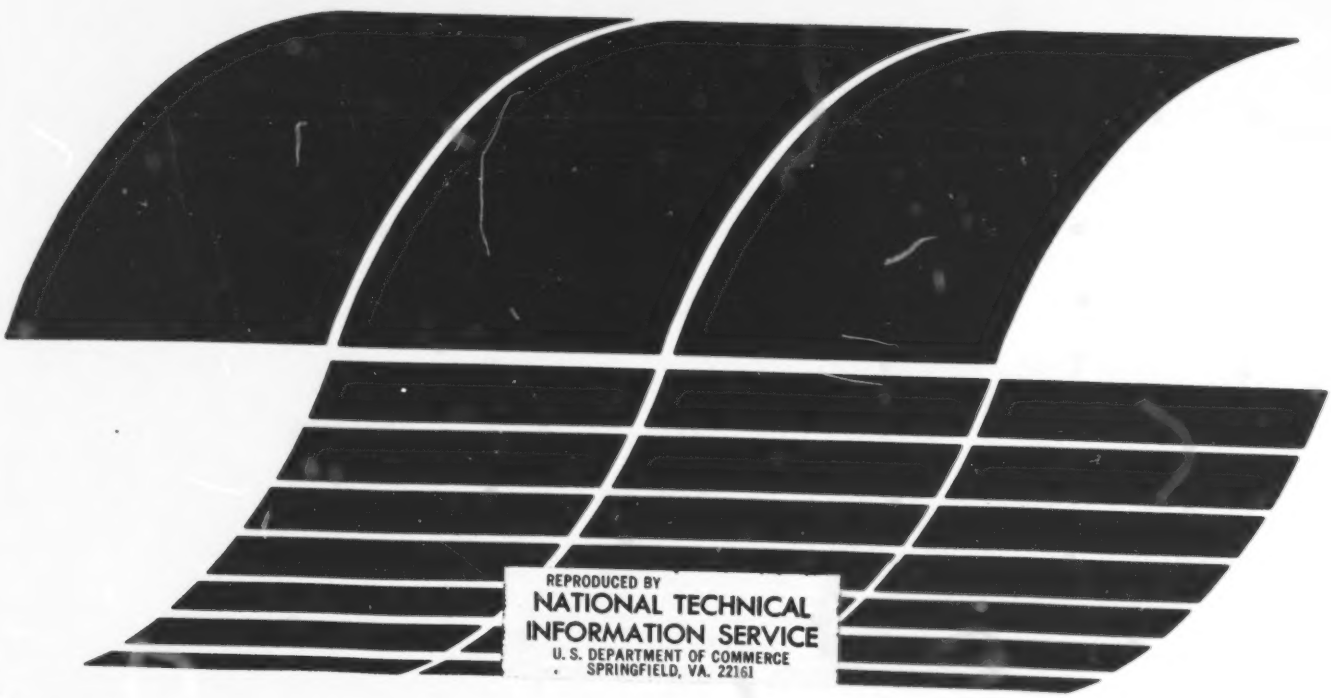
Interagency Energy/Environment R&D Program Report



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Office of Energy, Minerals, and Industry
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We also appreciate the assistance and guidance of our Project Officer, Mr. D. Bruce Harris.

We acknowledge that the disc-cylinder electrode geometry and method described in this report for ionization and particle charging are developments of Air Pollution Systems, Inc., Kent, Washington and the Electric Power Research Institute, Palo Alto, California, and that we have been advised by Air Pollution Systems, Inc. that United States and Foreign patents have been obtained and others applied for.*

We are not aware of the details of said patents or any pending applications and provide no assurance that practice of any of the systems or methods disclosed in this report do not infringe either said patents or any other private rights.

*U.S. Patent No. 4093430

INTRODUCTION

Filters used to collect fine particles in source sampling trains are troublesome in several ways. A large pump is usually required to pull the sample gas through a high efficiency filter, and many tests are terminated prematurely because of the large pressure drop that results as a dust cake builds up on the filter. This problem is especially severe when the test objective is to collect a large sample of submicron particles because the porosity is less than for large particles. Contamination of a sample with filter material or physical removal of the dust from the filter can also be problems.

This report describes the program carried out to design and evaluate the performance of an electrostatic collector to be used as an alternative to filters as a fine particle collector. Potential advantages of an ESP are low pressure drop and high capacity. Potential problems are unreliability and poor collection due to back corona or lack of particle adhesivity.

In the following section the theory of operation of the electrostatic collector is described, and the results of experimental measurements of electrical characteristics and collection efficiency are presented. Shop drawings of the system and its components are included in the Appendix.

SYSTEM DEVELOPMENT AND TESTING

DESIGN

The electrostatic precipitator back-up filter was designed to be operated at a nominal sample flowrate of 6.5 ft^3/min., at a temperature of 205°C, and to achieve near 100% collection of submicron particles. Since it is possible that there will be a need to operate the collector in situ, a secondary requirement was that the collector pass through a 4 inch diameter port. Furthermore, the system was designed to be convenient to operate and clean, and to require a minimum of operator training or attention.

Figure 1 is a schematic diagram illustrating the main features of the system that was selected. The collector is of a cylindrical geometry with the collection electrodes arranged concentrically to allow a large surface area to be contained within a relatively short outer cylinder. Disc and needle discharge electrodes were designed and fabricated, but only the disc-cylinder geometry was evaluated during this program. The system shown in Figure 1 is mechanically rugged and the collection electrode geometry is such that the flow is laminar at the design flowrate; thus, it is a simple matter to calculate particle trajectories and the electrode length required for 100% efficiency.

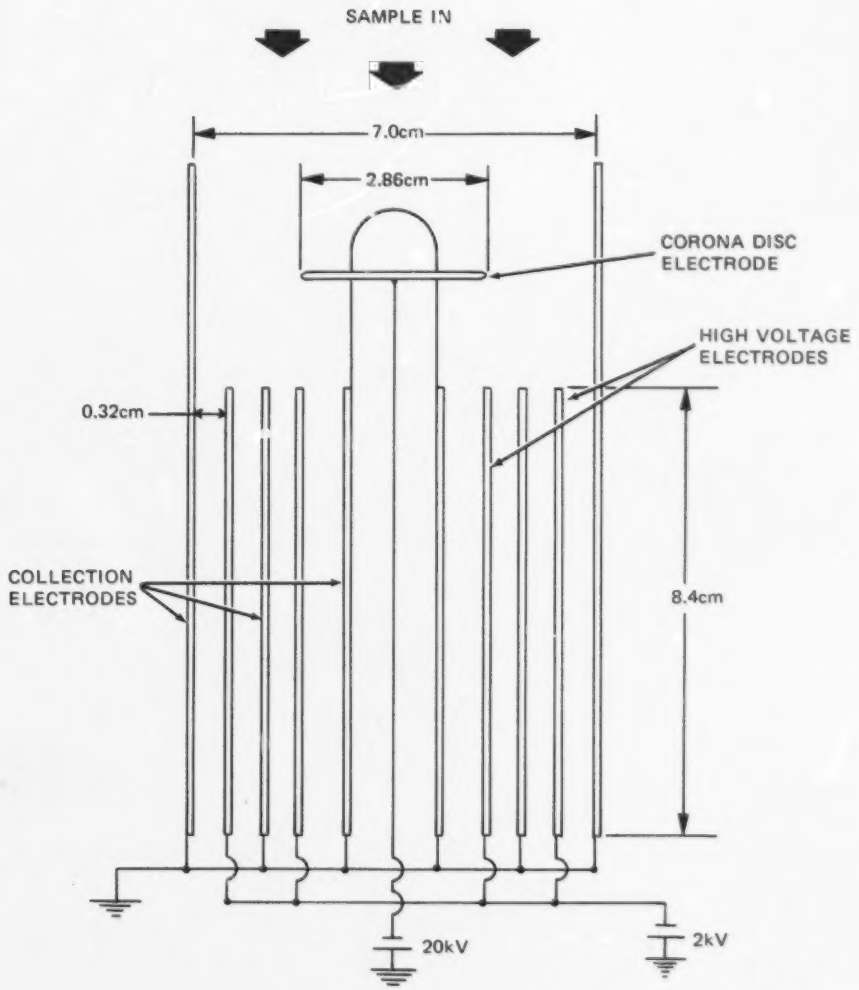

Figure 1. Schematic of the electrostatic collector with the disc discharge electrode installed.

Disc Discharge Electrode

The disc-cylinder design has been shown to be stable at very high values of corona field and current, and at high gas velocities.[1,2] The electric field (neglecting space charge) in the disc-cylinder geometry is given by the equation:[3]

$$E(r) = \frac{2V}{\pi \ln(b/a)} \left(\frac{1}{r}\right) \left[1 - \frac{\ln^2(b/r)}{\ln^2(b/a)}\right]^{\frac{1}{2}} , \qquad (1)$$

where V = applied voltage on the disc,
b = radius of the cylinder, and
a = radius of the disc.

At the cylinder, r = b and the equation becomes

$$E = \frac{2V}{\pi b \ln(b/a)} \qquad (2)$$

This is the minimum value of the electric field. Using the values $b = 3.5 \times 10^{-2}$m(1.38 inch), $a = 1.43 \times 10^{-2}$m(.56 inch), and V = 20kV, we obtain $E = 4.1 \times 10^{5}$ volts/m.

Experimental current-voltage characteristics for the disc-cylinder electrode geometry at 200°C and 7.5 SCFM show (Figure 2) that for V = 20kV, the current, i, is approximately 200 μA. The ion concentration can be determined from the equation $N = j/e\mu E$, where $j = i/2\pi bh$ = current density, h = width of the

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[1] Klemperer, H., and J. E. Sayers. "Design Aspects of an Electrostatic Precipitator for the Collection of Small Solids ahead of the Air Heater." Transactions of the ASME, Feb., 1956. pp. 317-326.

[2] Tassicker, O. J., and J. Schwab. "High-Intensity Ionizer for Improved ESP Performance." J. EPRI, June/July, 1977. pp. 56-61.

[3] Pontius, D. H., et al. "Fine Particle Charging Development." EPA-600/2-77-173, August, 1977. p. 125.

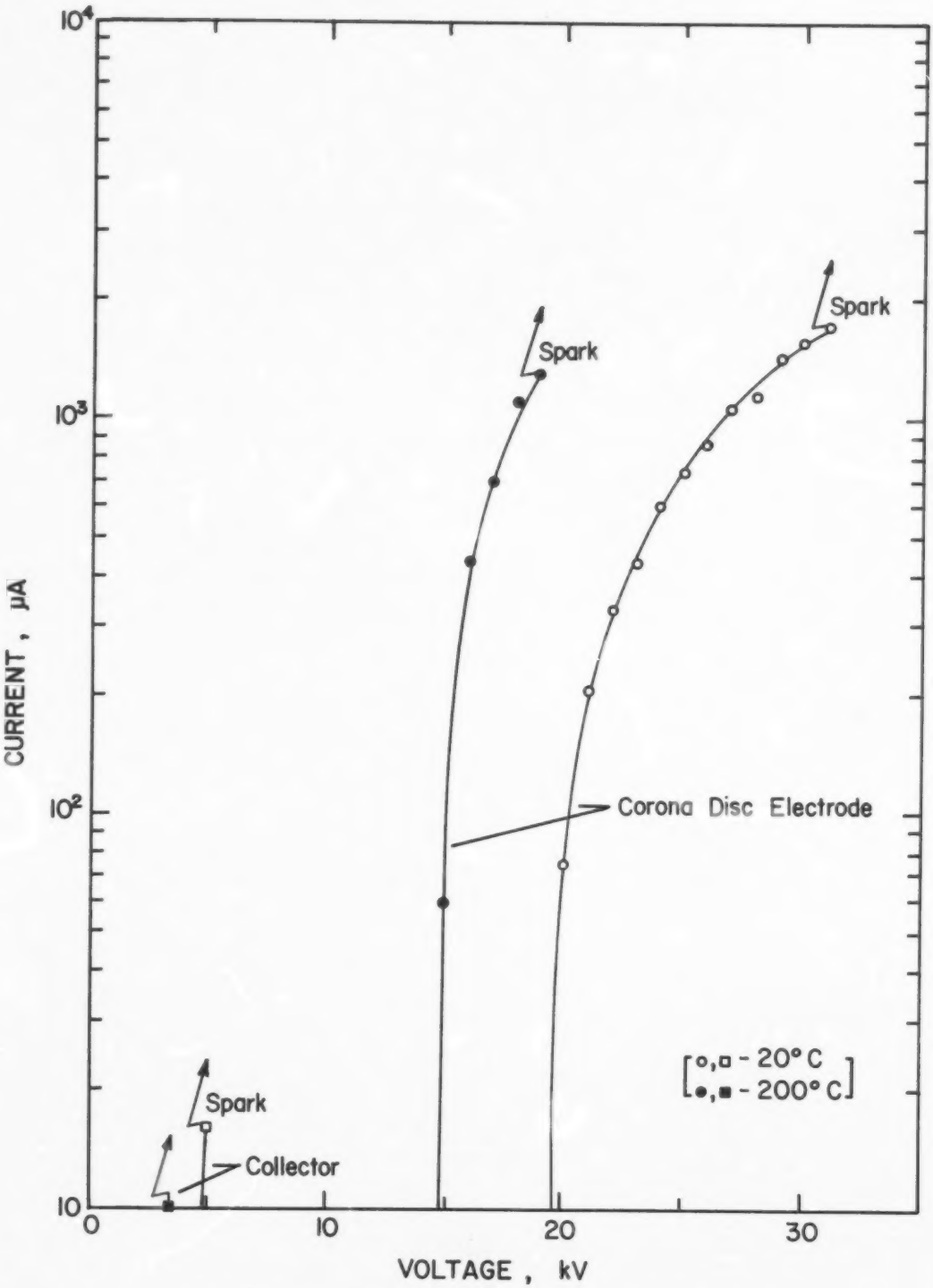


Figure 2. Current-Voltage characteristics of the ESP Collector at two temperatures and a sampling rate of 7.5 SCFM.

charging region on the cylinder wall, e = electronic charge, and μ = ion mobility. The average time of residence in the charging region is expressed t = h/v, where v = average gas velocity. Thus, the ion concentration-time product necessary for calculating particle charge is derived from

$$Nt = i/2\pi be\mu Ev. \tag{3}$$

A typical value of ion mobility is $\mu = 2.2 \times 10^{-4} m^2/V\text{-sec}$ and $e = 1.602 \times 10^{-19}$ coulombs. With a volume flowrate of $\mu = 6.5\ ft^3/min = 1.84 \times 10^{-1}\ m^3/min$, the average gas velocity, v, is given by v = u/A, where A is the annular area through which the gas passes. Therefore, using $A = 3.206 \times 10^{-3}\ m^2$, we obtain the value $v = 9.56 \times 10^{-1}$ m/sec. Thus, the ion concentration-time product is found to be $Nt = 6.58 \times 10^{13}\ sec/m^3$.

The mobility of particles having diameters between 0.5 μm and 0.05 μm was determined from the equation

$$m = qC/6\pi\alpha\eta, \tag{4}$$

where q = charge per particle, calculated from the sum of the diffusion and field charging equations,

C = Cunningham slip correction factor,

α = particle radius, and

η = viscosity of the medium.

A plot of particle mobility versus particle diameter was made to determine the diameter of the particle having the minimum mobility (Figure 3). For a particle of diameter 0.2 μm, the charge per particle in elementary units may be determined from theory to be $q = 2.76 \times 10^{-18}$ coulombs. It is assumed that all particles of equal diameter receive an equal charge although in fact there is a distribution of charges. The value determined above represents the mean of such a distribution where the particles are assumed

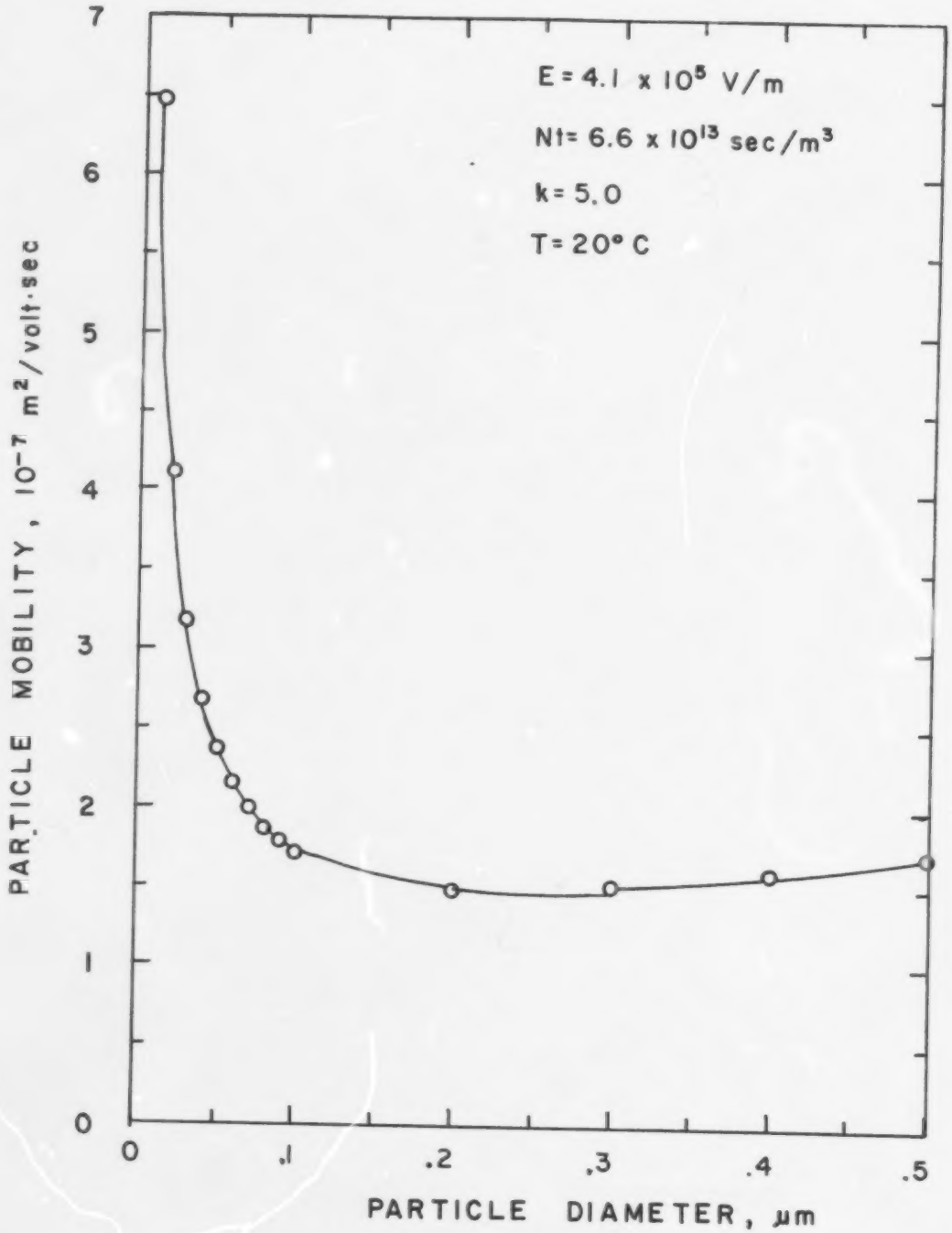


Figure 3. Particle mobility vs. particle diameter.

to have a relative dielectric constant of 5.0 and are at a temperature of 20°C. (Higher temperatures would give an increased mean charge on the particles.) The mobility of the 0.2 μm diameter particles is found to be $m = 1.51 \times 10^{-7} m^2/V\text{-sec}$.

The maximum distance a particle must travel before it reaches the collection electrode is just the plate separation, 0.32 cm (.125 in). With the concentric cylinders closely spaced, the flow is laminar (Reynolds number $Re \approx 132$) and the collection efficiency can be calculated from the particle trajectory. The velocity component downstream is u/A_c, where u is the sample flowrate and A_c is the open cross-sectional area of the collection zone ($A_c = 3.175 \times 10^{-3} m^2$). The velocity component toward the collection plate is the migration velocity, w, which is equal to the product of the electric field and particle mobility. The length of the collection plate required for 100% theoretical collection efficiency is then

$$l = \frac{u}{A_c} \cdot \frac{d}{w} \quad , \tag{5}$$

where $d = 3.2 \times 10^{-3} m$ is the cylinder spacing. If we choose a value of 6.25×10^5 volts/m for the collecting field (2 kV applied), the migration velocity for the 0.2 μm diameter particles is $9.44 \times 10^{-2} m/sec$, and l is equal to 3.27 cm. Thus, the 8.4 cm collector plate length used in the final design is extremely conservative.

Needle Discharge Electrode

The sharp needle discharge electrode system was subjected to the same type of analysis as the disc system described above. The current-voltage characteristics for the needle-cylinder electrode geometry are shown in Figure 4. An applied voltage of V = 16 kV corresponds to a total current of i = 200 μA. The ion concentration-time product is determined from Equation 3 using

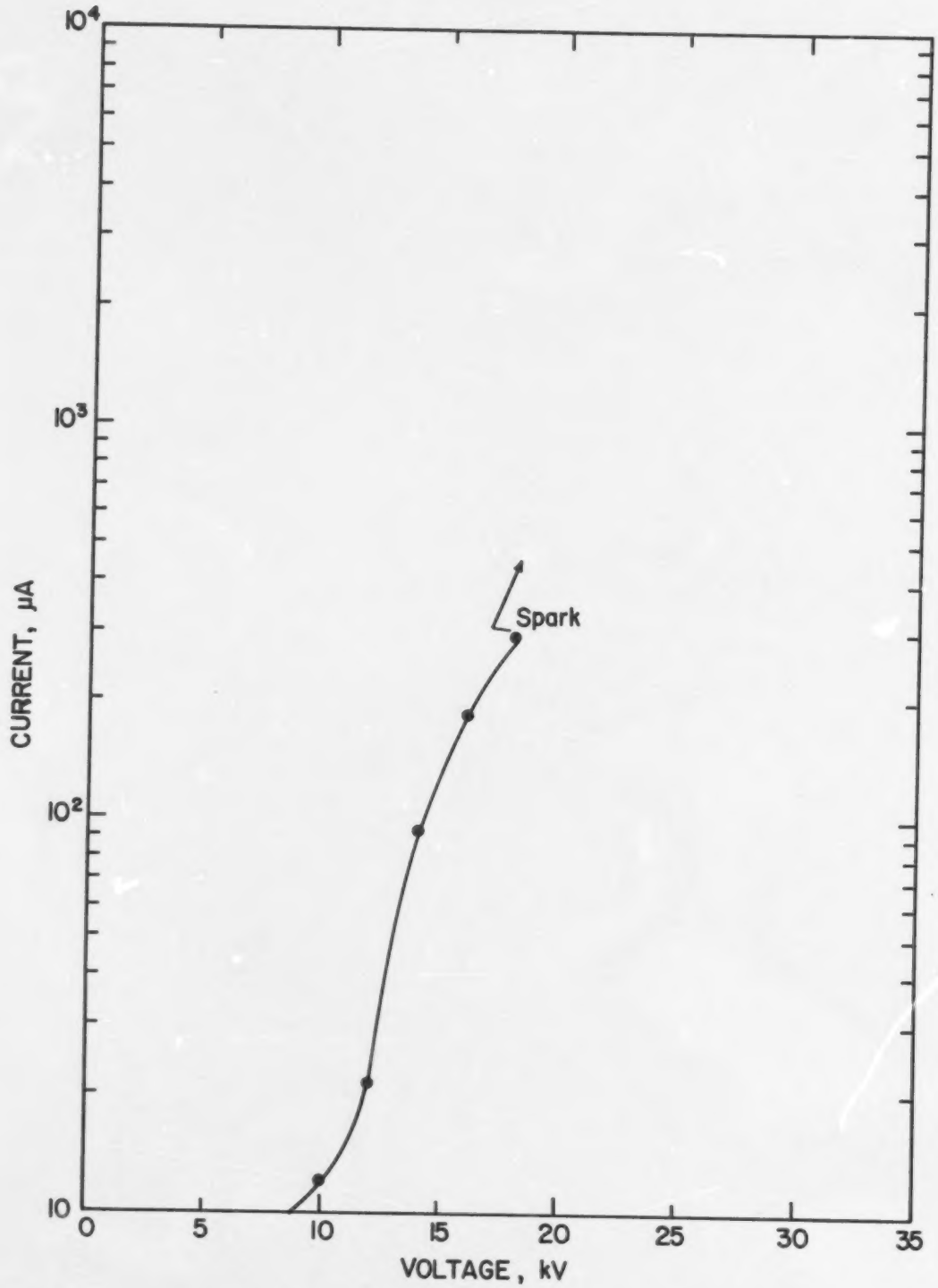


Figure 4. Current-Voltage Characteristics of the ESP Collector with the Needle Discharge Electrode and at T = 200°C and Flowrate = 7.5 SCFM.

the value of the average electric field strength, $E = V/b = 4.6 \times 10^{5}$ volts/m, $v = 8.86 \times 10^{-1}$ m/sec, $\mu = 2.2 \times 10^{-4}$ m^2/V-sec, and $e = 1.602 \times 10^{-19}$ coulombs. The resulting value is $Nt = 6.33 \times 10^{13}$ sec/m^3.

The mobility of the 0.2 μm diameter particles is determined from Equation 4 to be 1.57×10^{-7} m^2/V-sec. This gives a migration velocity, w, of 9.8×10^{-2} m/sec. Thus, Equation 5 gives the length of collection plate required for 100% theoretical collection efficiency to be l = 3.1 cm. Here again, the selection of 8.4 cm as the collector plate length in the final design is very conservative.

The prototype ESP collector was fabricated from glass-filled teflon and type 316 stainless steel. Figure 5 is an assembly drawing of the ESP collector. Complete shop drawings are included in this report as an appendix.

Performance

Figure 6 illustrates the experimental arrangement used to evaluate the ESP collector in preliminary laboratory tests. A lognormal aerosol of approximately 1 μm mass median diameter and geometric standard deviation of 2.0 was generated by nebulizing a 0.1% solution of fluorescein in 0.1N NH_3. The aerosol was pumped through the ESP collector with the disc discharge electrode installed. The size dependent collection efficiency was determined by measuring the particle size distribution at the ESP outlet, with the power on and off, using a Thermosystems Model 3030 Electrical Aerosol Analyzer. The results of these experiments are summarized in Table I. It is clear from the table that the ESP is capable of achieving the desired high collection efficiency for submicron particles. Laboratory tests were not conducted with the needle discharge electrode.

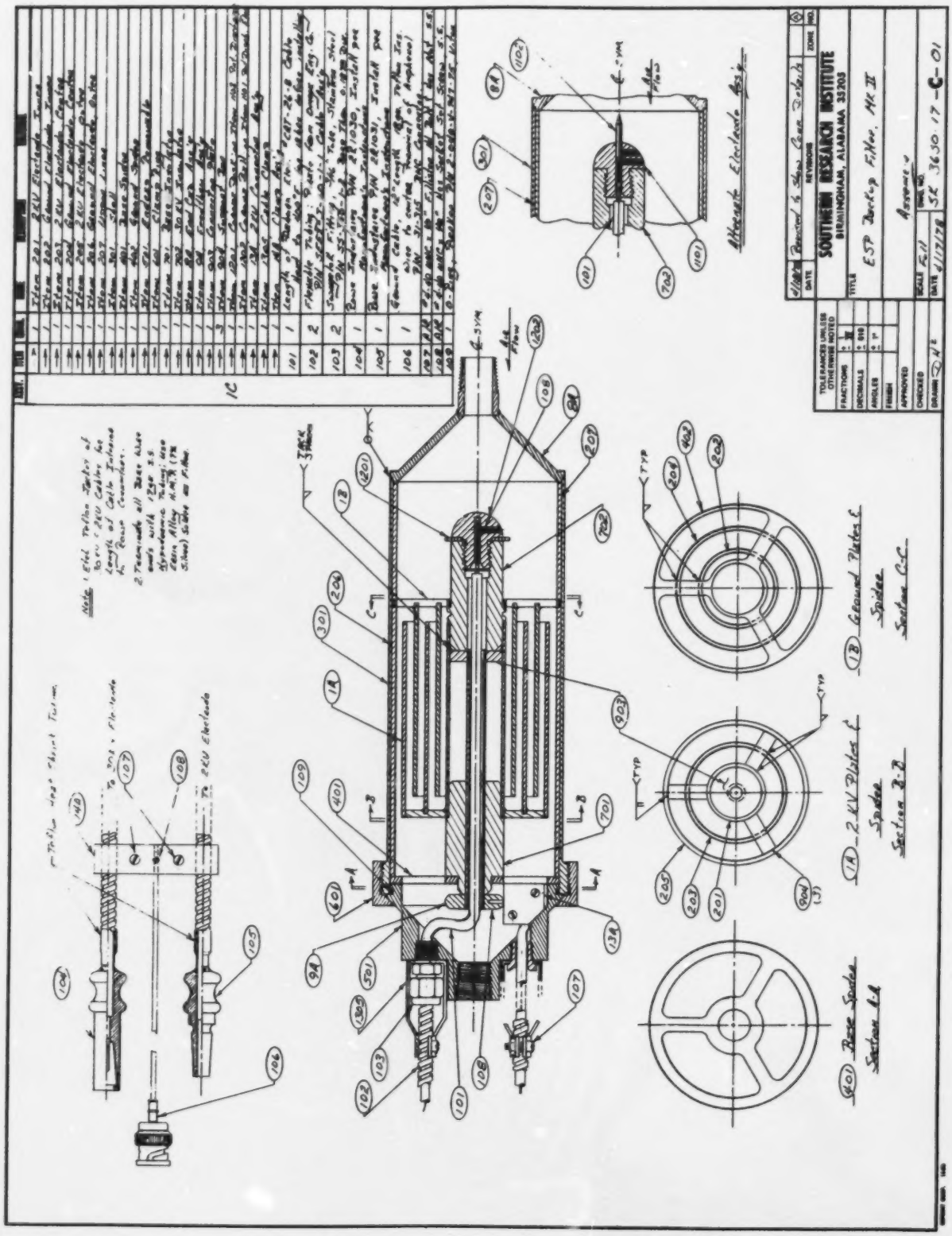


Figure 5. ESP Collector Assembly Drawing.

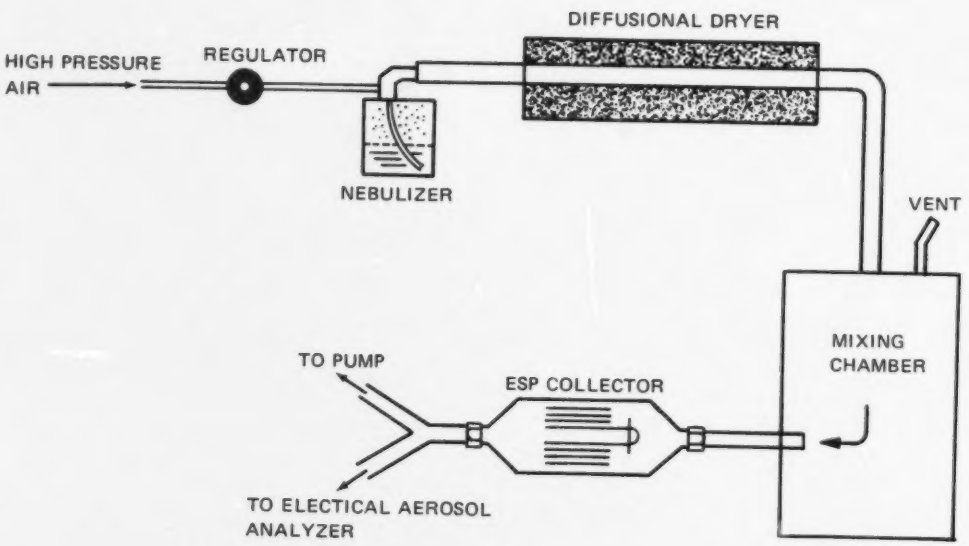


Figure 6. Laboratory setup for evaluating the electrostatic collector.

TABLE I

Laboratory Determination of the
Collection Efficiency of the ESP Collector
With the Disc Discharge Electrode

Corona Voltage = 25 kV
Corona Current =200 μA
Collector Voltage = 2 kV
Ammonium Fluorescein Aerosol

Particle Size (μm)	0.0133	0.0237	0.0422	0.0750	0.133	0.237	0.422	0.750
Flowrate (ACFM)	Collection Efficiency (%)							
.898	99.86	99.93	100.00	99.97	100.00	99.98	100.00	100.00
2.97	-	99.77	100.00	99.93	99.95	99.50	99.62	100.00
4.65	99.76	100.00	99.99	100.00	100.00	100.00	100.00	99.60
5.82	99.34	99.88	100.00	100.00	100.00	99.96	100.00	99.85

Tests were conducted to determine the efficiency of the ESP collector when sampling redispersed fly ash of high resistivity. The purpose of these tests was to investigate possible deleterious effects due to back corona and heavy dust loading.

Figure 7 illustrates the experimental setup for the fly ash tests. A sample of dust-laden gas was withdrawn from a duct downstream from a pilot-scale precipitator. Fly ash was injected into the heated gas stream with a sandblaster. The precipitator was not energized and thus acted as a settling chamber to effectively reduce the mass median diameter of the sampled particles without severely diminishing the number concentration of fine particles. The extracted sample passed through a heated probe, a cyclone, and into the ESP collector. A filter was located downstream of the ESP to collect any dust that penetrated it, for determinations of the collection efficiency.

Two tests were run with the disc-cylinder electrode system, each for six hours, with a dust loading of 1.88 g/m^3 at the precipitator inlet. One test was run at 25°C, and the other at 171°C. After six hours' testing, there was no noticeable increase in pressure drop across either of the filters. After each test, the ESP collector was disassembled, immersed in a beaker containing distilled water, and agitated ultrasonically. For these tests, the resultant suspension was filtered. The filters were then dried and weighed to determine the amount of particulate material collected.

The test conditions and results for the disc-cylinder system fly ash experiments are presented in Table II. Again, the ESP collector performed well, with efficiencies of 96 and 98% for the two tests.

Experiments with the needle discharge electrode in the ESP collector were not performed. The efficacy of the needle-cylinder geometry in field applications has not been determined.

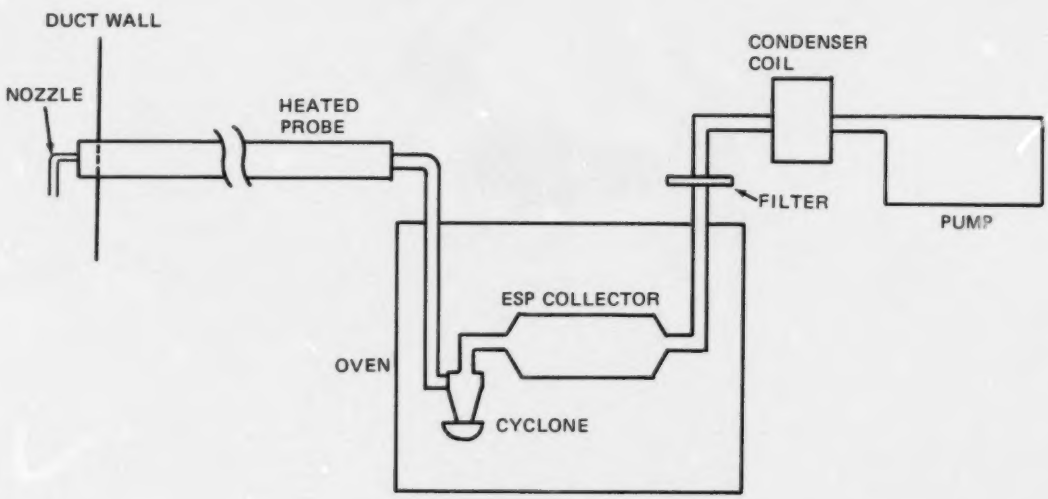


Figure 7. Experimental setup for evaluation of the ESP collector using redispersed flyash.

TABLE II

Collection Efficiency of the ESP Collector
With the Disc Discharge Electrode

	Test 1	Test 2
Corona Voltage	22 kV	19 kV
Corona Current	190 μA	200 μA
Collector Voltage	2 kV	2 kV
Flowrate	142 slpm	142 slpm
Temperature	25°C	171°C
Run Time	6 hours	6 hours
Dust Loading	1.88 g/m^3	1.88 g/m^3
Cyclone Catch	40 g	0.56 g
ESP Catch	0.435 g	0.704 g
Filter Catch	0.016 g	0.017 g
Efficiency of ESP	96.3%	97.6%

Power Supply Package

The power supply package for the ESP collector has been designed to provide essentially "turnkey" operation. All operating parameters have been pre-set in order to provide simple field operation. The front panel controls consist of a power switch, operating/fault displays, and screwdriver adjustments for collector voltage and ionizing current.

The power supply package consists of two major subsystems (see Figure 8): the collector voltage power supply with associated display, and the ionizer power supply with associated control and monitor circuits. The display circuits for the collector voltage consists of a window comparator which monitors the output of a voltage divider. Whenever the monitored voltage is outside the pre-set window, the pulse stretching circuit (a monostable multivibrator with a one-second output pulse) turns on the fault display. This display will remain on as long as the collector voltage is outside the pre-set window. The ionizer power supply consists of a Spellman voltage programmable modular supply and control circuitry. A control voltage is derived by integrating the difference between a reference voltage and the voltage drop across a buffered resistance in the ground return line. This converts the power supply into an adjustable constant current source. The display circuits for the ionizer are essentially identical to those of the collector voltage supply with the exception that they monitor the voltage drop across the buffered resistance.

The last item of interest is the "ground fault detection and high voltage inhibit" circuit. Whenever the current in the ground return line drops below a low pre-set value (nominally 12 μA) for a period of time greater than 100 milliseconds, the outputs of both power supply modules are inhibited. This insures that if

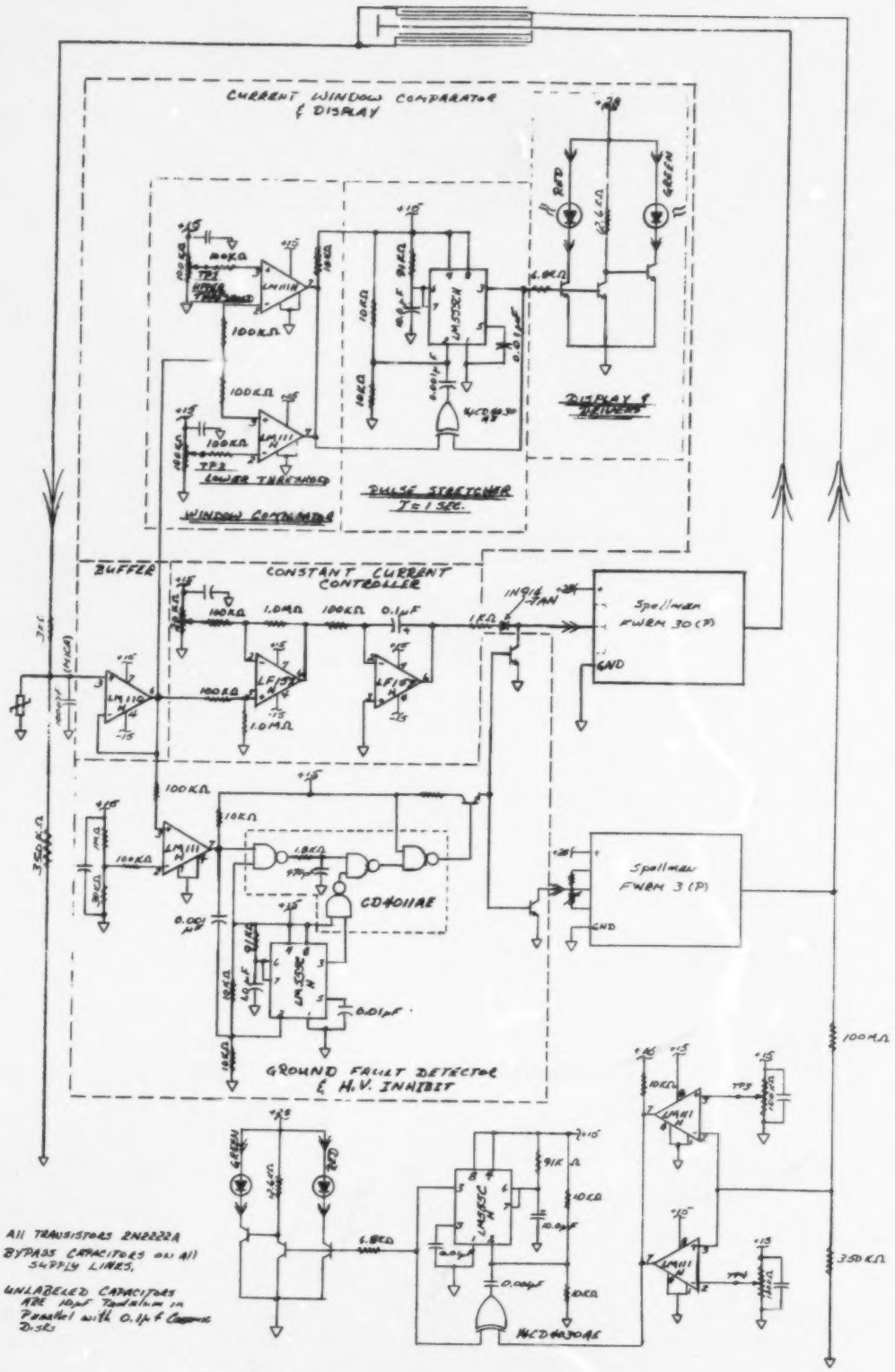

CURRENT WINDOW COMPARATOR & DISPLAY
BUFFER
CONSTANT CURRENT CONTROLLER
PULSE STRETCHER T≈1 SEC.
GROUND FAULT DETECTOR & H.V. INHIBIT
CD4011AE
Spellman FWRM 30 (P)
Spellman FWRM 3 (P)
GND
All TRANSISTORS 2N2222A
BYPASS CAPACITORS ON All SUPPLY LINES.
UNLABELED CAPACITORS ARE 10μF Tantalum in Parallel with 0.1μF Ceramic Disks

Figure 8. Power Supply Package Circuitry.

either the external ionizer connection or ground return line connection is broken, no high voltage hazard will exist.

Please note that at the time of this report, no extensive testing had been performed on this power supply package. Therefore, some modifications may be made at a future date.

Power Supply Specifications

Ionizer Current: Constant 15 μA to 1 mA (upper limit dependent on electrode geometry) adjustable

Collector Voltage: 1.8 KV to 3.0 KV adjustable

Operating Temperature: Control & Display Circuits -25°C to + 85°C
High Voltage Supplies: 0°C to +70°C

Power Requirements: 105 to 120 VAC, 6A(max.)

SUMMARY

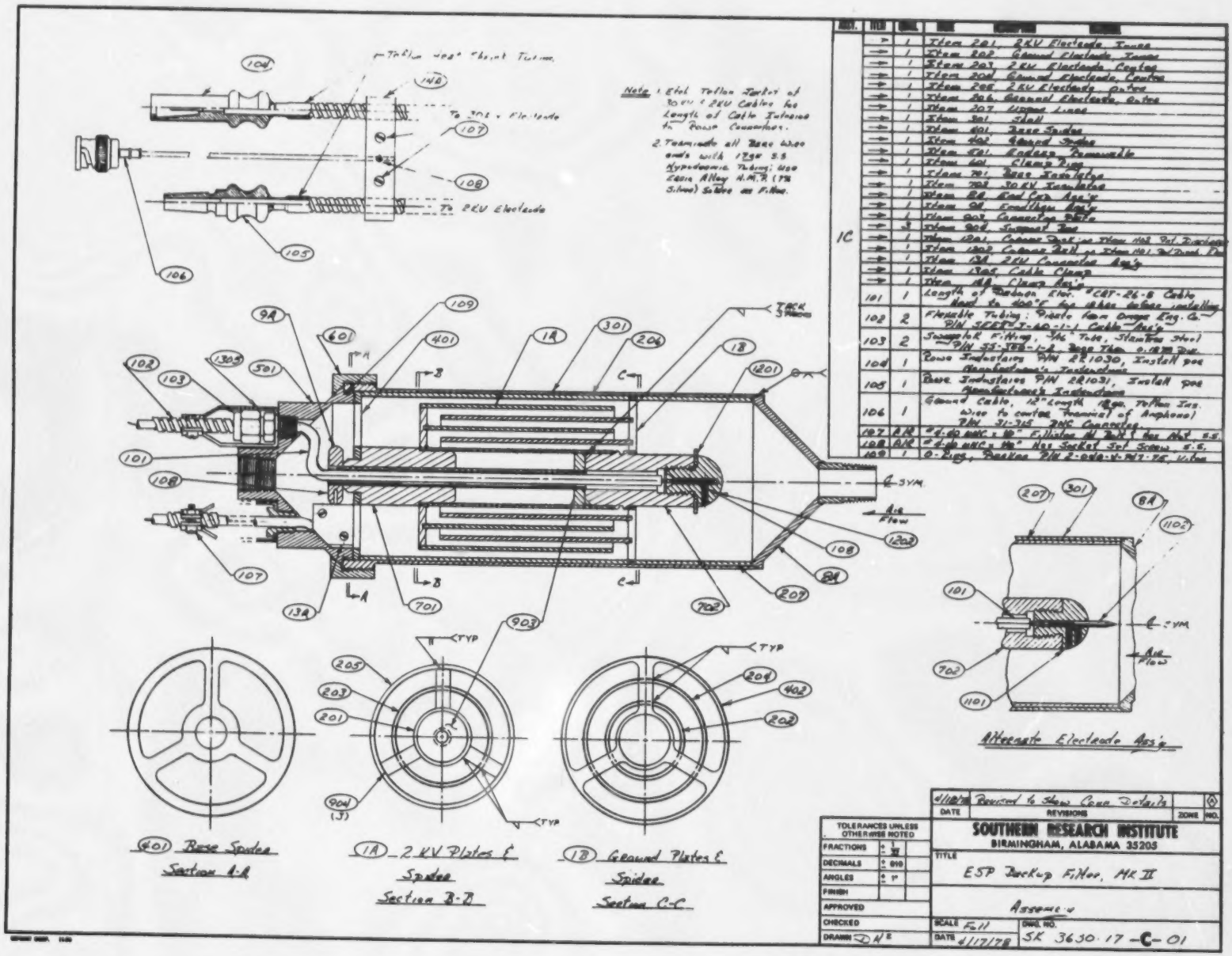
The ESP collector is a highly efficient collector of submicron particles. When set to 200 μA on the corona disc electrode and 2 kV on the collector (both well below breakdown values), no further adjustments are necessary for proper operation. The power supply developed for the ESP collector facilitates correct operation. Since there is a potential for degraded performance due to back corona if the collected particles are of high resistivity, it is suggested that the collector be routinely used with a back-up filter following it in the sampling train. If experience has shown the system to operate reliably at a particular source, the filter can be eliminated.

After the sample is collected, the ESP is disassembled, immersed in a suitable liquid, and agitated ultrasonically. The wash can be filtered or evaporated to dryness, depending on the nature of the dust and the objectives of the test.

The electrostatic collector prototype developed and tested in this research effort fulfills the design criteria: near 100% collection of submicron particles when operated at a nominal sample flowrate of 6.5 ft^3/min and a temperature of 200°C, sized to fit through a 4 inch diameter port for in situ operation, convenient to operate, and clean.

APPENDIX

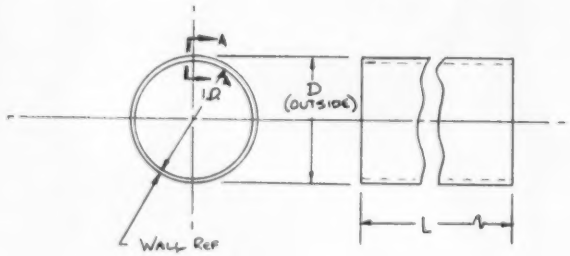
SHOP DRAWINGS OF THE ESP COLLECTOR


Note: 1. Etal Teflon Jacket of 30 KV & 2KV Cables has Length of Cable Intersing to Power Connectors.
2. Terminate all Base Wire ends with 17ga S.S Hypodermic Tubing; use Loctite Alloy H.M.P. (1% Silver) Solder on Fillet.
To 30KV Electrode
To 2KV Electrode
Item 201 2KV Electrode Inner
Item 202 Ground Electrode Inner
Item 203 2KV Electrode Center
Item 204 Ground Electrode Center
Item 205 2KV Electrode Outer
Item 206 Ground Electrode Outer
Item 207 Upper Liner
Item 301 Shell
Item 401 Base Spider
Item 402 Ground Spider
Item 501 Rodress Removable
Item 601 Clamp Ring
Item 701 Base Insulator
Item 702 30KV Insulator
Item 801 End Cap Assy
Item 802 Endplug Assy
Item 803 Connector Plate
Item 804 Support Bar
Item 1201 Ground Post see Item 402 for Details
Item 1202 Ground Post see Item 401 for Details
Item 1301 2KV Connector Assy
Item 1302 Cable Clamp
Item 1303 Clamp Assy
Length of Teflon Etal "CBT-26-B Cable Heat to 400°C typ when teflon insulation
Flexible Tubing: Plastic Foam Dunger Eng. Co. P/N SCEFT-40-1-1 Cable Ties
Swagelok F-Nut, 3/16" Tube, Stainless Steel P/N SS-316-1-2 Base Item 0.125 Dia.
Rowe Industries P/N 221030, Install per Manufacturer's Instructions
Rowe Industries P/N 221031, Install per Manufacturer's Instructions
Ground Cable, 12" Length 18ga. Teflon Ins. wire to center "monical of Amphenol P/N 31-318 BNC Connectors.
#4-40 UNC x 3/8" F.Hex Std Brass Hex Nut S.S
#4-40 UNC x 3/8" Hex Socket Set Screw, S.S.
O-Ring, Parker P/N 2-026-V-747-75 Viton
Base Spider
Section A-A
2 KV Plates & Spider
Section B-B
Ground Plates & Spider
Section C-C
Alternate Electrode Assy
Revised to Show Cone Details
SOUTHERN RESEARCH INSTITUTE
BIRMINGHAM, ALABAMA 35205
ESP Backup Filter, MR II
Assembly
SK 3630-17-C-01
TOLERANCES UNLESS OTHERWISE NOTED
FRACTIONS
DECIMALS
ANGLES
FINISH
APPROVED
CHECKED
DRAWN
SCALE Full
DATE 4/17/78

QUAN.	ITEM	MAT'L	DESCRIPTION
	201	1	INNER 2KV ELECTRODE 1.05 OD x .884 ID x .083 WALL 316 SS TUBING 3.375 LONG
	202	1	INNER GROUND ELECTRODE 1⅜ OD x 1.26 ID x .120 WALL 316 SS TUBING 3.312 LONG
	203	1	CENTER 2KV ELECTRODE 1.90 OD x 1.610 x .145 WALL 316 SS TUBING 3.312 LONG
	204	1	CENTER GROUND ELECTRODE 2⅜ OD x 1.939 ID x .218 WALL 316 SS TUBING 3.312 LONG
	205	1	OUTER 2KV ELECTRODE 2½ OD x 2.37 ID x .065 WALL 316 SS TUBING 3.375 LONG
	206	1	OUTER GROUND ELECTRODE 3.0 OD x 2.760 ID x .120 WALL 316 SS TUBING 4.40 LONG
	207	1	UPPER LINER 3.0 ID x 2.760 ID x .120 WALL 316 SS TUBING 1.50 LONG

ROUND EDGE

SECTION A-A
TYP BOTH ENDS
(NO SCALE)



P/N	Dim "D" (O.D.)	Dim "L" (LENGTH)	WALL (REF)	I.D.
201	1.01	3.375	.063	.884 (S)
202	1.375	3.312	.057	1.260 (S)
203	1.750	3.312	.062	1.625
204	2.125	3.312	.062	2.00
205	2.50 (S)	3.315	.065	2.370 (S)
206	2.895 ◁	4.65	.062	2.760 (S)
207	2.895 ◁	2.00	.062	2.760 (S)

(S) DENOTES STOCK SIZE AS IS

NOTE:

▷ 2.895 DIA MAY BE CHANGED AS REQUIRED TO OBTAIN FREE FIT IN PART # SK 3630-301

DATE	REVISIONS	ZONE	NO.

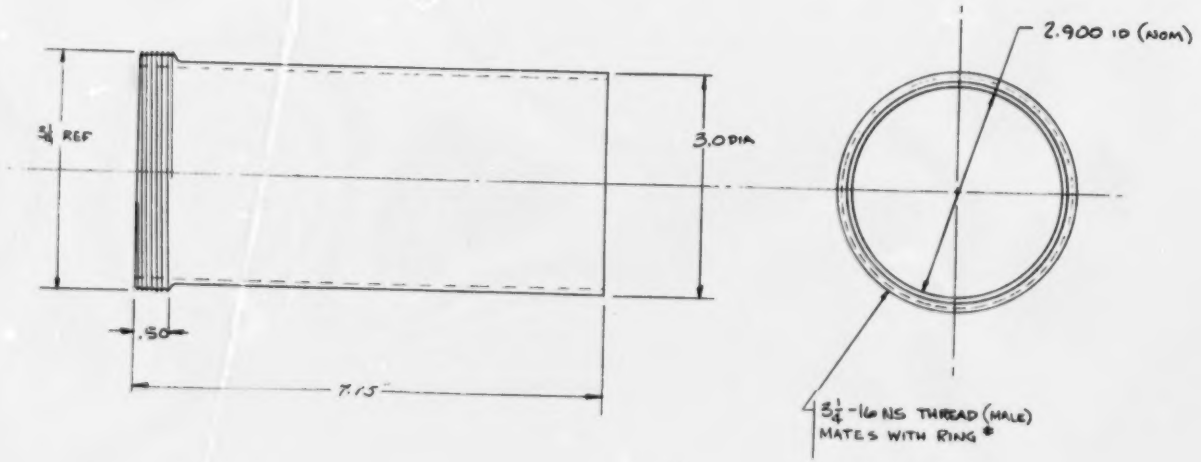
TOLERANCES UNLESS OTHERWISE NOTED
FRACTIONS ± 1/32
DECIMALS ± .010
ANGLES ± 1°
FINISH
APPROVED
CHECKED ZH
DRAWN TROY SIMS

SOUTHERN RESEARCH INSTITUTE
BIRMINGHAM, ALABAMA 35205

TITLE
COLLECTION PLATES

SCALE NONE
DATE 6/05/77
DWG. NO. SK 3630-17-C-02

ASSY.	REF	QUAN.	DESCRIPTION	MATERIAL
301		1	SHELL 3½ OD x 2.900 ID x .300 WALL 316 SS TUBING	



TOLERANCES UNLESS OTHERWISE NOTED	
FRACTIONS	± 1/32
DECIMALS	± .010
ANGLES	± 1°
FINISH	
APPROVED	
CHECKED	
DRAWN	

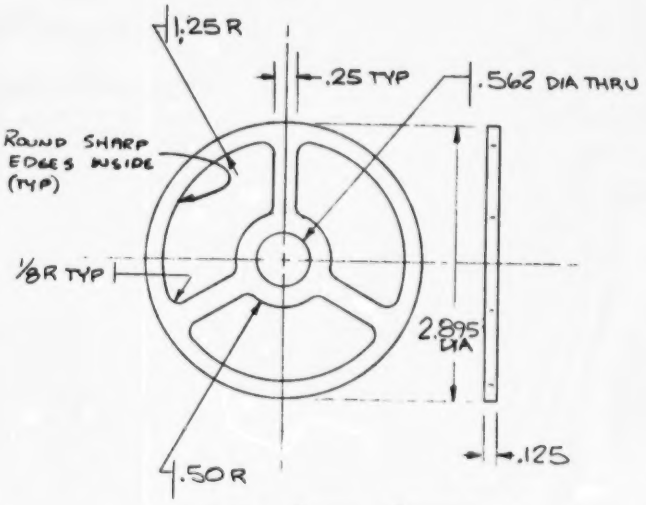
DATE	REVISIONS	ZONE	NO.

SOUTHERN RESEARCH INSTITUTE
BIRMINGHAM, ALABAMA 35205

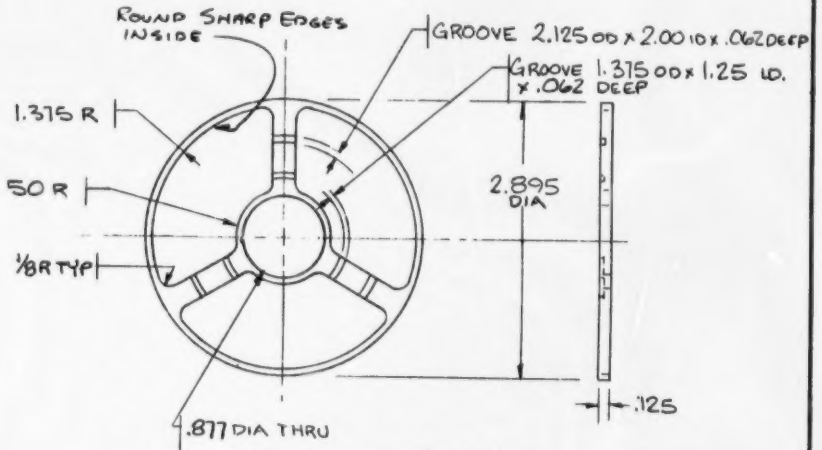
TITLE: SHELL, ESP FILTER

SCALE: Full
DATE: 26 Aug 77
DWG NO. SK3630-17 C-03

ASSY.	ITEM	QUAN.	NAME	DESCRIPTION	MATERIAL
	401	1	BASE SPIDER	2.875 x .125	316 S.S.
	402	1	GROUND SPIDER	2.875 x .125	316 S.S.



-401 BASE SPIDER



-402 GROUND SPIDER

TOLERANCES UNLESS OTHERWISE NOTED		
FRACTIONS	± 1/32	
DECIMALS	± .010	
ANGLES	± 1°	
FINISH		
APPROVED		
CHECKED DAZ		
DRAWN T. BOWBRIDGE		

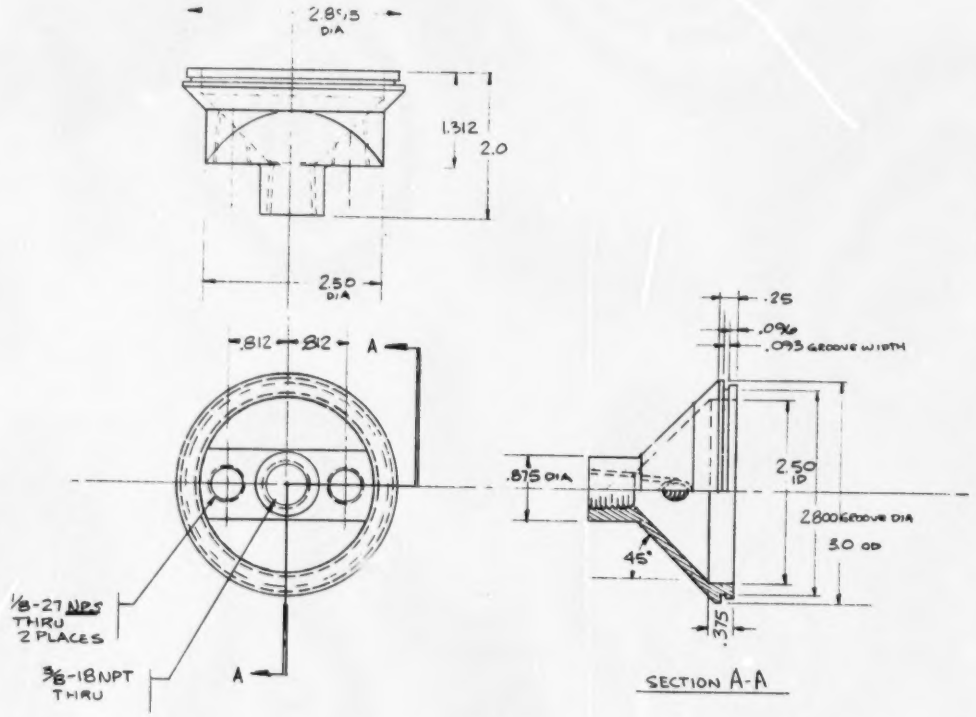
DATE	REVISIONS	ZONE	NO

SOUTHERN RESEARCH INSTITUTE
BIRMINGHAM, ALABAMA 35205

TITLE: SUPPORT SPIDERS

SCALE: FULL
DATE: 28 SEP 77
DWG. NO. 3630-17-B-04

ASSY	ITEM	QTY	DWG NO	DESCRIPTION	MATERIAL
	501	1		END CAP 3.0 ODX 2 DIA	316 SS



-501 END CAP

TOLERANCES UNLESS OTHERWISE NOTED	
FRACTIONS	± 1/32
DECIMALS	± .010
ANGLES	± 1°
FINISH	
APPROVED	
CHECKED	[illegible]
DRAWN	[illegible]

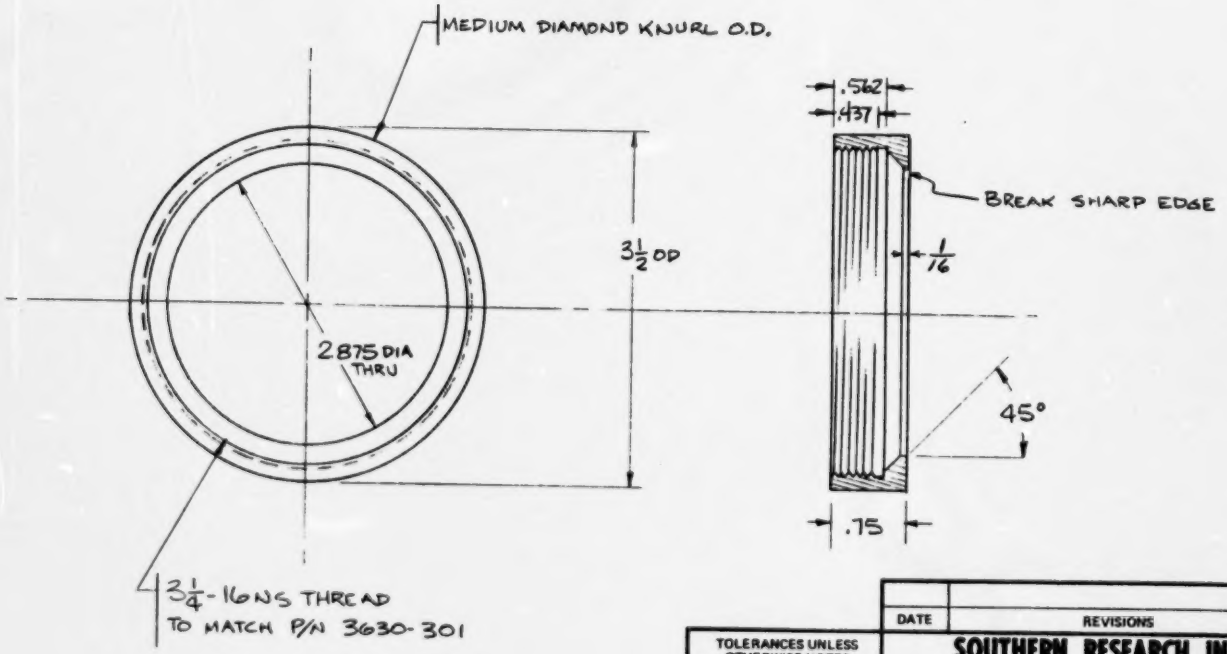
DATE	REVISIONS	ZONE	NO.

SOUTHERN RESEARCH INSTITUTE
BIRMINGHAM, ALABAMA 35205

TITLE: END CAP, ESP FILTER (REMOVABLE)

SCALE: FULL
DWG NO: SK 3630-17-C-05
DATE: 26 SEP 77

ASSY.	ITEM	DETAIL	NAME	DESCRIPTION	MATERIAL
	601	1	CLAMPRING	$3\frac{1}{2}$ ODx.15	Monel



-601 CLAMP RING

TOLERANCES UNLESS OTHERWISE NOTED		
FRACTIONS	± 1/32	
DECIMALS	± .010	
ANGLES	± 1°	
FINISH		
APPROVED		
CHECKED	DH/Z	
DRAWN	TEDWORTHY	

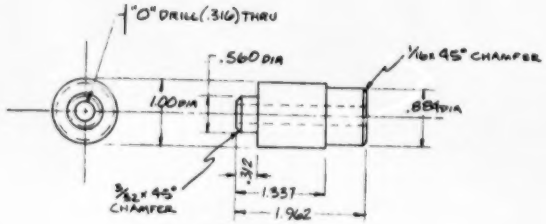
DATE	REVISIONS	ZONE	NO.

SOUTHERN RESEARCH INSTITUTE
BIRMINGHAM, ALABAMA 35205

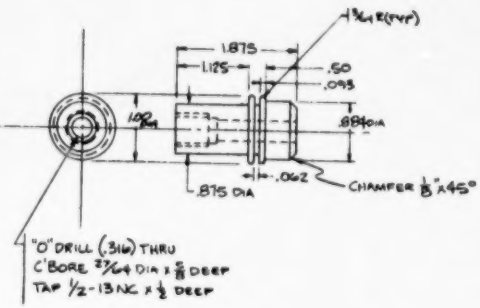
TITLE: CLAMP RING

SCALE: FULL
DATE: 27 SEP 77
DWG. NO.: SK3630-17-B-06

PART	NO	QUAN	DESCRIPTION	MATERIAL
	701	1	INSULATOR 1.00 DIA x 1.962 Lg GLASS FILLED TEFLON	
	702	1	INSULATOR, .90 DIA x 1.875 Lg GLASS FILLED TEFLON	



-701 BASE INSULATOR



-702 30KV INSULATOR

TOLERANCES UNLESS OTHERWISE NOTED	
FRACTIONS	± 1/32
DECIMALS	± .010
ANGLES	± 1°
FINISH	
APPROVED	
CHECKED	DA/E
DRAWN	TBOWDEN

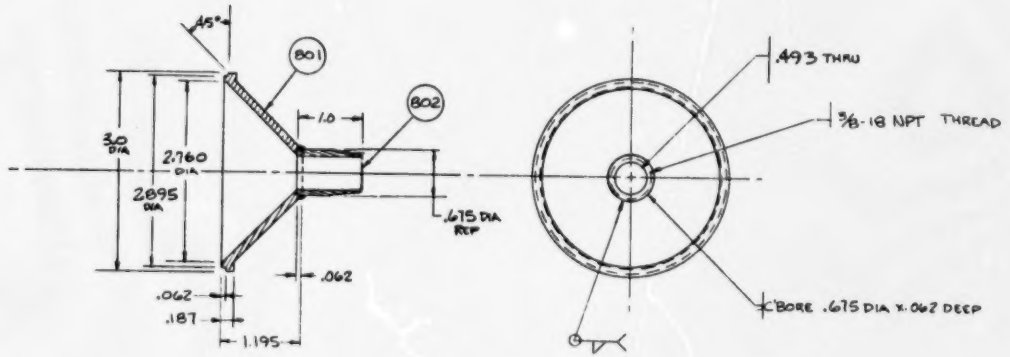
DATE	REVISIONS	ZONE	NO.

SOUTHERN RESEARCH INSTITUTE
BIRMINGHAM, ALABAMA 35205

TITLE: INSULATORS, ESP FILTER

SCALE: FULL
DWG NO: SK 3630-17-C-07
DATE: 28 Sept 77

REV.	ITEM	QUAN.	DESCRIPTION	MATERIAL
	801	1	CONE 3.0 DIA x 1.195	316 SSTL
8A	802	1	NIPPLE 3/8 SCH 40 PIPE x 1" LG (.675 OD x .091 WALL) 316 SSTL	



-8A END CAP ASSY

TOLERANCES UNLESS OTHERWISE NOTED	
FRACTIONS	± 1/32
DECIMALS	± .010
ANGLES	± 1°
FINISH	
APPROVED	
CHECKED DA	
DRAWN TEW 28-DEC	

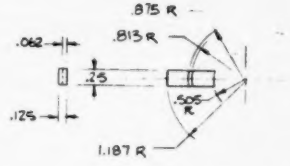
DATE	REVISIONS	ZONE	NO.

SOUTHERN RESEARCH INSTITUTE
BIRMINGHAM, ALABAMA 35205

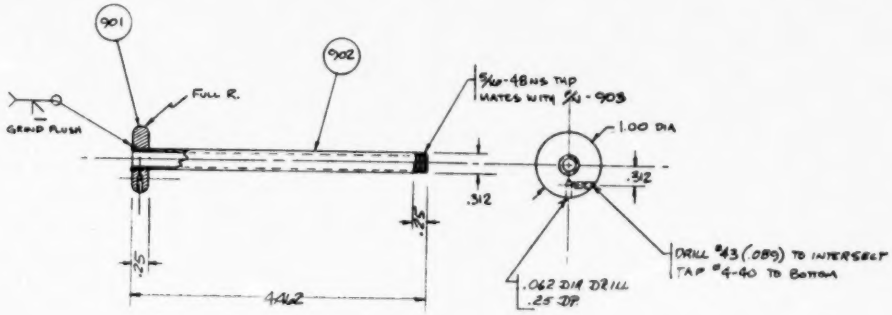
TITLE: END CAP, FIXED, ESP FILTER

SCALE: FULL
DWG NO: SK3630-17-C-08
DATE: 20 SEP 77

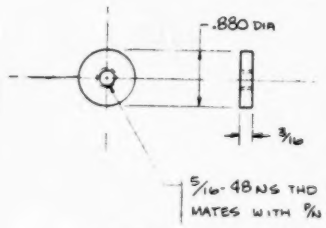
ITEM	PIECES	MATERIAL	DESCRIPTION	MATERIAL
901	1	CORONA RING	1.00 DIA x .25 THK	316 SS
902	1	TUBE	5/16 OD x .243 ID (.036 WALL)	316 SS TUBING
903	1	PLATE	3/16 x .880 DIA	316 SS
904	3	SUPPORT BAR	.75 x .125 x .25	316 SS



-904 2KV SUPPORT BAR



-9A FEED-THRU ASSY



CONNECTOR PLATE - 903

3/14/78	2KV Spacer Cone		
DATE	REVISIONS	ZONE	NO.

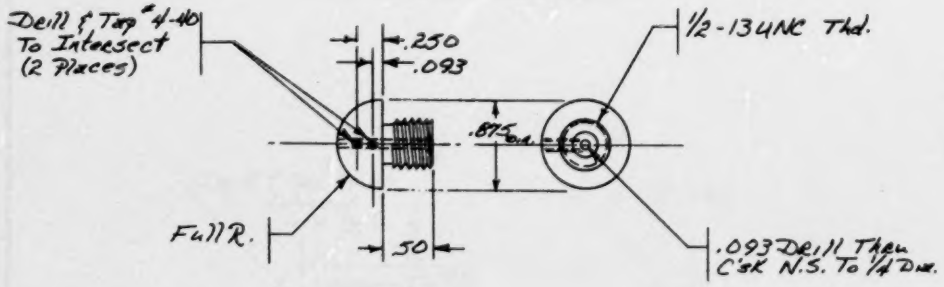
TOLERANCES UNLESS OTHERWISE NOTED
FRACTIONS ± 1/32
DECIMALS ± .010
ANGLES ± 1°
FINISH
APPROVED
CHECKED C. W.
DRAWN BOWDLOVE

SOUTHERN RESEARCH INSTITUTE
BIRMINGHAM, ALABAMA 35205

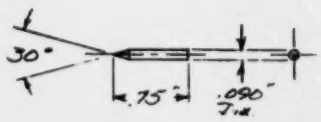
TITLE
FEED-THRU TUBE, CONNECTOR PLATE
& 2KV SUPPORT BAR

SCALE FULL
DATE 28 SEP 77
DWG NO SK3630-17-C-09

ASSY.	ITEM	QUAL.	NAME / DESCRIPTION / MATERIAL
	1101	1	Point Discharge Electrode, 0.875"Dia x 0.937"L 316 Stainless Steel
	1102	1	Discharge Point, 0.090"Dia x 0.75"L 316 Stainless Steel



Point Discharge Electrode, Item (1101)



Discharge Point, Item (1102)

TOLERANCES UNLESS OTHERWISE NOTED		
FRACTIONS	± 1/32	± 1/64
DECIMALS	± .010	± .002
ANGLES	± 1°	
FINISH		
APPROVED		
CHECKED		
DRAWN	L.H.	

DATE	REVISIONS	ZONE	NO.

SOUTHERN RESEARCH INSTITUTE
BIRMINGHAM, ALABAMA 35205

TITLE: Alternate Electrode

SCALE: Full
DATE: 12 June 1970

DWG. NO. 3630-17 -B- 11